BOSC Review of ORD Clean Air Research Program (CARP)

Session 2: Air Quality Management

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Air Quality Research in the MYP

- Air quality research supports both Long-Term Goals (LTGs) of the CARP MYP

    - *LTG 1: Reduce uncertainty in standard setting and air quality management decisions due to advances in air pollution science*
        - NAAQS development and implementation

    - *LTG 2: Reduce uncertainties in linking health and environmental effects to air pollution sources*
        - "Source-to-health" linkage
        - Multi-pollutant research
        - Accountability
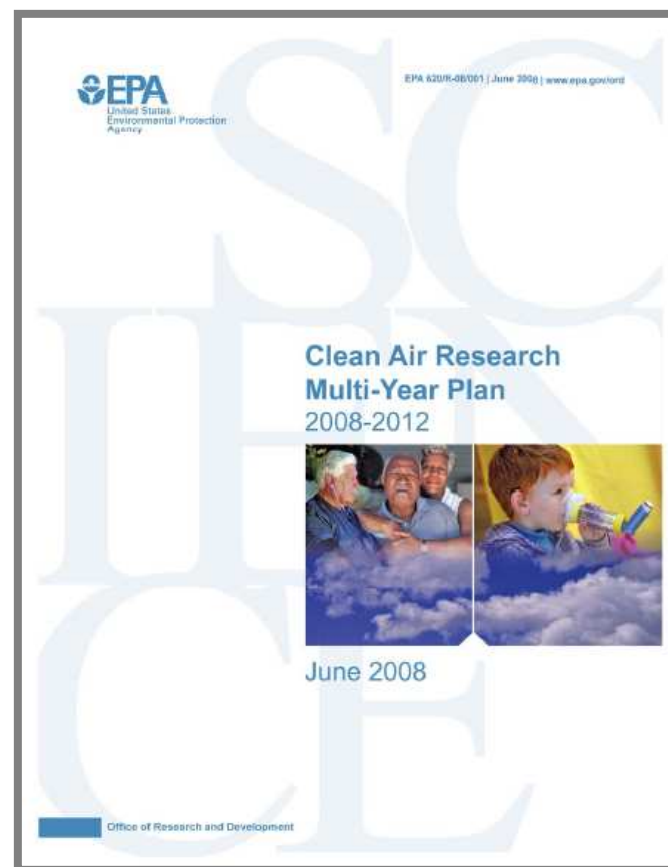
Research Drivers

- Science gaps associated with NAAQS implementation
  - Continuing O_3, $PM_{2.5}$ non-attainment issues
    - Source characterization and identification
    - Air quality characterization
    - Control strategy development
  - Evolving (more stringent) standards
  - Multi-pollutant aspects

- Insights and recommendations from NRC Reports
  - Research Priorities for Airborne PM: IV (2004)
    - PM emissions inventory and air quality models for NAAQS
    - Enhancing air quality monitoring for research
    - From PM to a multi-pollutant approach
    - Accountability
  - Air Quality Management in the US (2004)
    - Improve emissions tracking
    - Enhance air pollution monitoring
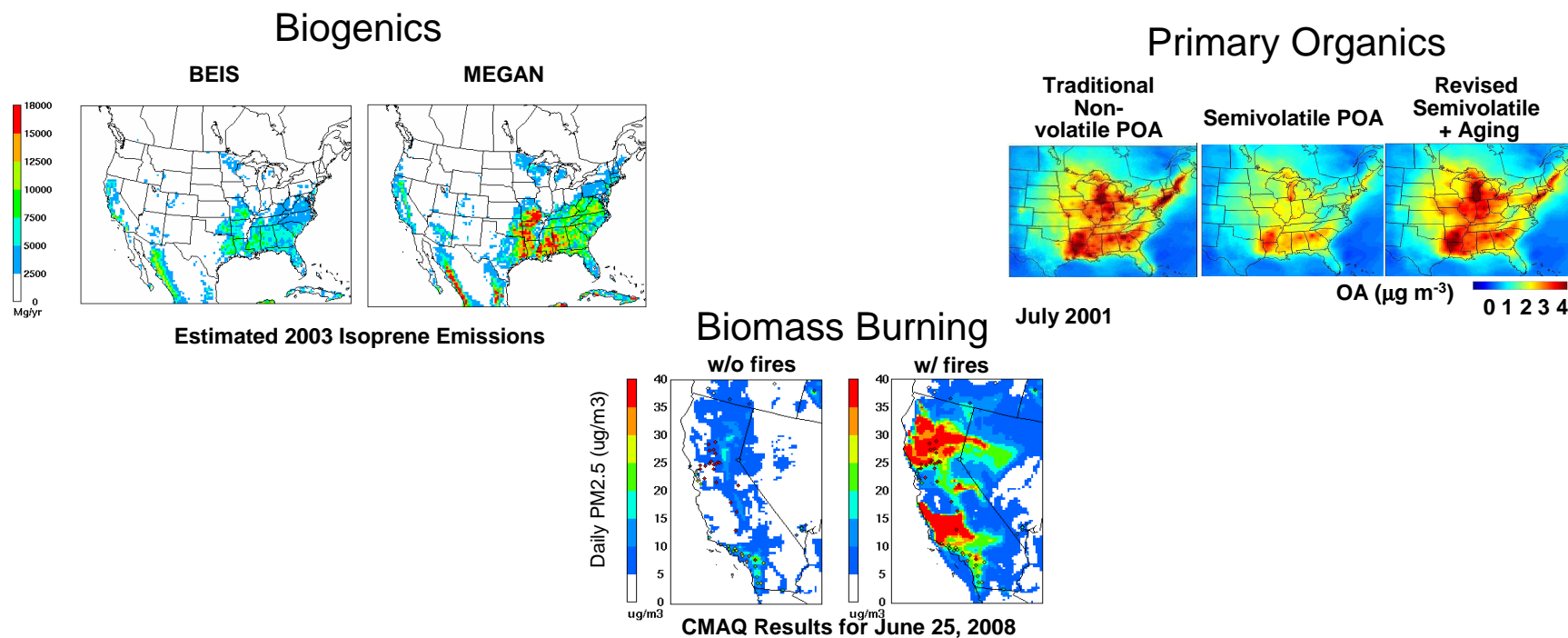   - Improve modeling
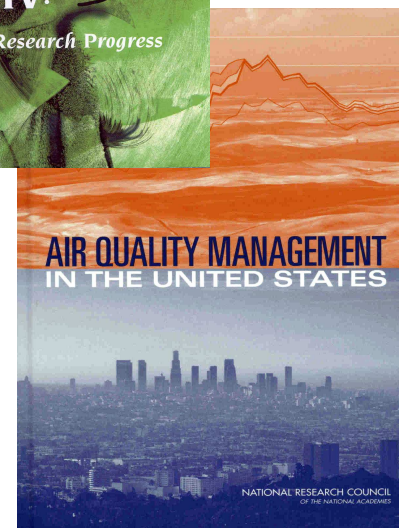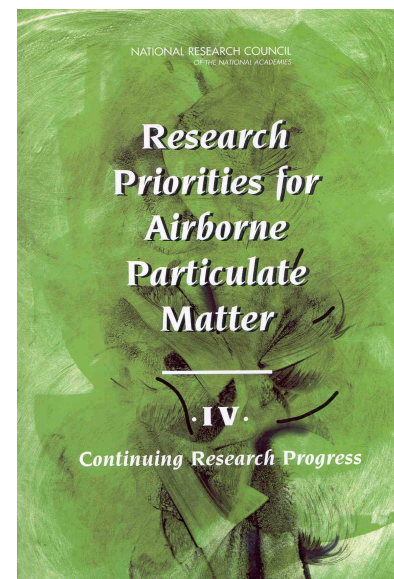
Session Themes

- ## Source Emissions
  - Estimation and evaluation

- ## Ambient Measurements
  - Air quality characterization and process insights

- ## Air Quality Modeling
  - Applications driving development and evaluation

- ## Extending Applications of Methods and Models
  - Linking to ecosystem, exposure, and climate assessments

Source Emissions Research

- ## Goals

  - Improve understanding of sources contributing to air quality (non-attainment) problems

  - Improve emission inputs needed for air quality models, such as CMAQ model

Biogenics

BEIS   MEGAN

Estimated 2003 Isoprene Emissions

Primary Organics

Traditional Non-volatile POA   Semivolatile POA   Revised Semivolatile + Aging

OA (μg m^{-3})   0 1 2 3 4

July 2001

Biomass Burning

w/o fires   w/ fires

Daily PM2.5 (ug/m3)

CMAQ Results for June 25, 2008

Source Emissions Research Accomplishments

- Characterization of emissions from wildland and prescribed fires
  - Satellite imagery has greatly aided fire characterization
  - OC estimation from fires

- Advancements in biogenic emissions
  - Measurements of isoprene, sesquiterpenes, monoterpenes from variety of tree species
  - MEGAN, BEIS model evaluations

- Ammonia emissions
  - Key precursor for inorganic PM
  - Flux measurements have provided new insights into bi-directional nature of emissions/deposition

- Anthropogenic source sampling
  - Semi-volatile organic measurements show that POA is largely gas-phase at emission
  - Estimating PM emissions factors in near-source environments

- Integration of inverse, source-based, and receptor models
  - Characterize and improve emissions estimates for air quality model
  - Real-world (incl. satellite) measurements show more temporal/seasonal variability than national emissions inventories
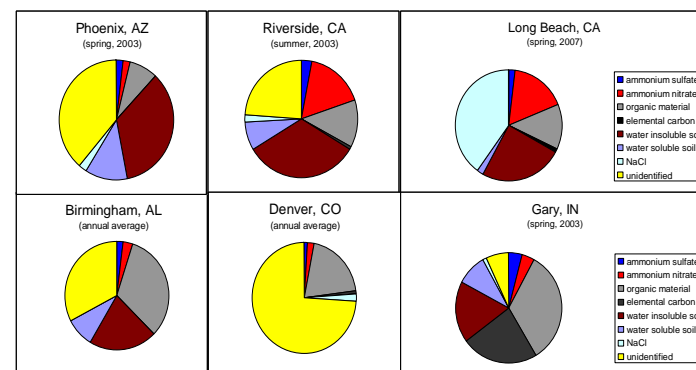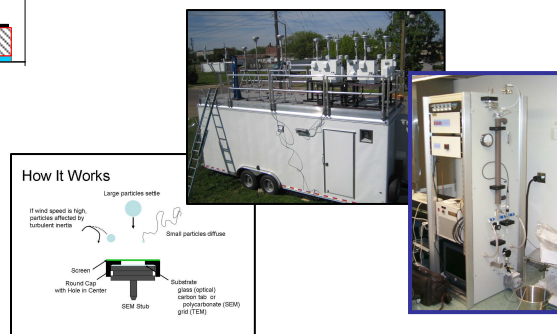
Ambient Measurements Research

- ## Goals

    - Development, application and evaluation of sampling and analytical methods

    - Provide insights into source contributions, atmospheric processes, ambient concentration variability
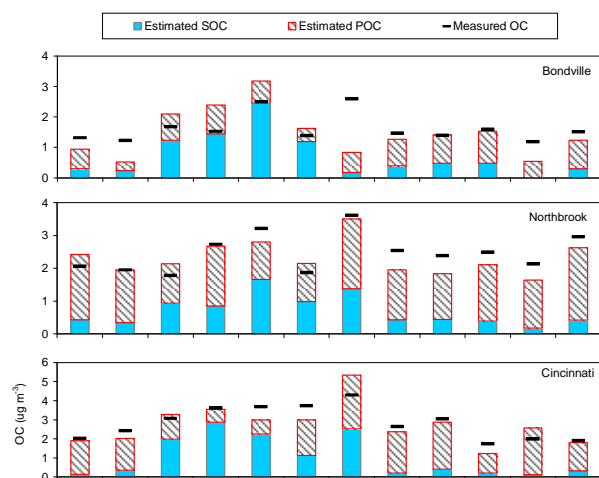
Organic Carbon Measurements

Methods Evaluation


Coarse Particle Composition

Ambient Measurements Research Accomplishments

- Methods to support NAAQS compliance
  - New FEMs for continuous $PM_{2.5}$ and $PM_{10-2.5}$ monitors
  - High resolution semi-continuous PM species measurements for source apportionment
  - Low resolution passive methods for spatial distributions and source apportionment

- Improved understanding of SOA formation
  - New field and laboratory measurements of SOA and precursors
  - Resulting in development of new SOA formation pathways from isoprene, sesquiterpenes, and benzene

- Coarse PM
  - Spatial variability within urban areas
  - Regional composition of coarse PM

- Mercury fate and transport
  - Measurement technologies for atmospheric Hg fluxes
  - Support for modeling studies and source apportionment
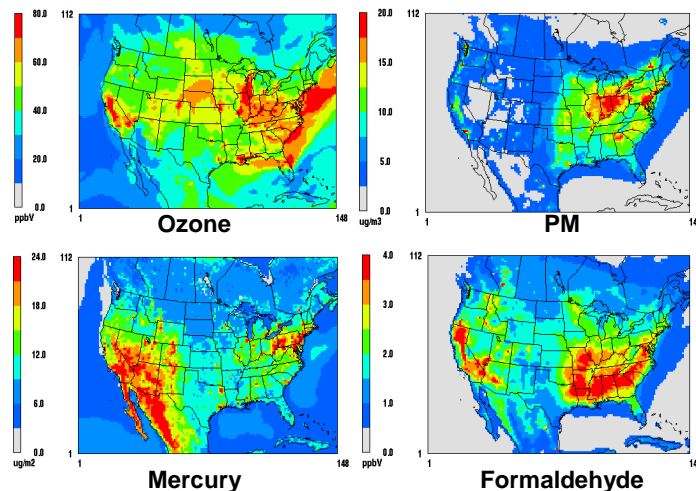
Air Quality Modeling Research

- ## Goals
  - Development, application, evaluation, and refinement of air quality modeling systems to improve their reliability and credibility for research and policy assessments
  - Provide insights into model sensitivities to data and processes to guide related physical, chemical, meteorological research

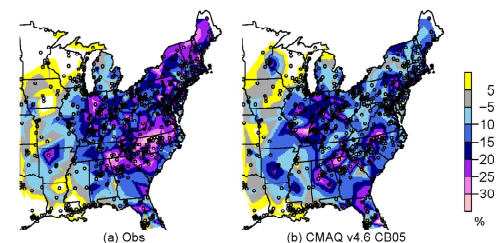### Multipollutant Modeling
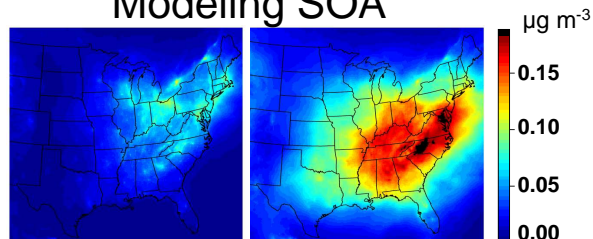
Modeling SOA

CMAQ results before (left) and after (right) revising the aromatic SOA treatment [Aug 2006 average]

Ozone

PM

Mercury

Formaldehyde

Model Evaluation

(a) Obs   (b) CMAQ v4.6 CB05

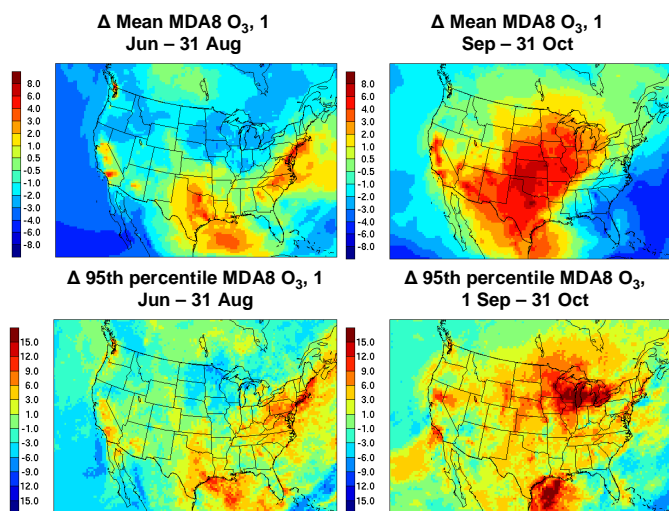CMAQ modeling response to NOx SIP Call

Air Quality Modeling Research Accomplishments

- PM process improvements
  - Incorporation of new SOA formation pathways into CMAQ, including biogenic, aromatic, and in-cloud mixed-phase processes
  - Development of Volatility Basis Set approach to semi-volatile primary and secondary organics; life-cycle description of organic aerosol
  - Dynamic interaction between fine and coarse model aerosols
  - Source-tracking tools for primary organics

- Extension of chemical kinetic mechanisms
  - Inclusion of 43 HAPS, including Hg
  - Gas, aqueous, and heterogeneous (esp. N_2O_5) chemistry

- Air quality-meteorology interactions
  - Improved consistent boundary layer and land-surface treatments in air quality and meteorology models
  - Transition to WRF model for meteorology input

- Framework for model evaluation
  - Development and application of operational, diagnostic, dynamic, and probabilistic modes of evaluation
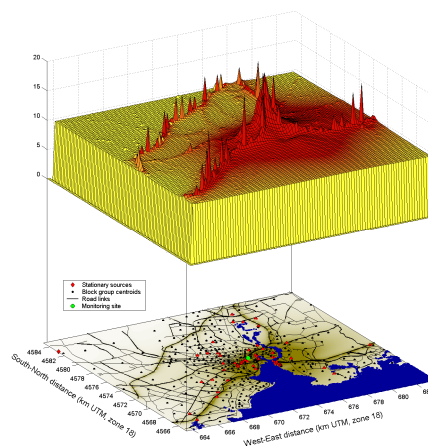
Extended Applications Research

- ## Goals

  - Link air quality methods, measurements, and models to assessments for ecosystem health, human exposures, and climate change impacts
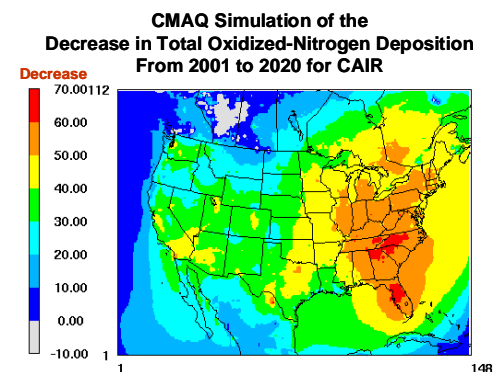
Climate Change Impacts

Δ Mean MDA8 O_3, 1 Jun – 31 Aug

Δ Mean MDA8 O_3, 1 Sep – 31 Oct

Δ 95th percentile MDA8 O_3, 1 Jun – 31 Aug

Δ 95th percentile MDA8 O_3, 1 Sep – 31 Oct

Exposure Assessment

Integration of Regional and Local Scale Models

Ecosystem Impacts

CMAQ Simulation of the Decrease in Total Oxidized-Nitrogen Deposition From 2001 to 2020 for CAIR

Extended Applications Research Accomplishments

- Linking to ecosystem assessments
  - Development of Watershed Deposition Tool to bridge between air and watershed models
  - Identified sources and role of regional NOx, SOx, and NH3 in deposition to ecosystems

- Linking to climate change assessments
  - Climate Impacts on Regional Air Quality (CIRAQ) project – pilot study on downscaling global climate and chemistry model projections to 2050 on U.S. air quality
  - Development and application of sector-based emission projection models (e.g., MARKAL)

- Linking to human exposure assessments
  - Developed "hybrid" model approach using CMAQ and AERMOD models to reach local fine-scale concentration estimates
  - Used hybrid model concentration results in exposure modeling (SHEDS, HAPEM) in New Haven, CT pilot study

Impacts and Outcomes

- Model applications informing:
  - Policy decisions
    - Clean Air Interstate Rule (CAIR)
    - Clean Air Mercury Rule (CAMR)
    - Renewable Fuels Standards (RFS-2)
  - Ecosystem Assessments
    - Chesapeake Bay and Tampa Bay
  - Global Change Assessment
    - Assessment of the Impact of Global Change on US Regional Air Quality (NCEA)

- Measurement studies informing:
  - Residual Non-attainment areas (St. Louis, Detroit)
  - Mercury Deposition (Steubenville)

Impacts and Outcomes (cont)

- ## Improvements in measurement and modeling tools
  - FEMs for continuous $PM_{2.5}$ and $PM_{10-2.5}$
  - National Emissions Inventory
  - MOVES - new mobile source emissions model
  - MEGAN (Model of Emissions of Gases and Aerosols from Nature)
  - CMAQv4.7; latest (2008) public release of model
 - PMF and Unmix receptor modeling tools

Designation	Number of Designations by Pollutant Since 2005							
	PM_{10}	$PM_{2.5}$	$PM_{10-2.5}$	O_3	NO_2	SO_2	CO	Totals
Federal Reference Methods (FRMs)	1	3	3		3		3	13
Federal Equivalent Methods (FEMs)	2	10	2	4		3		21
Modifications to FRMs	9	3		2	5	8	8	35

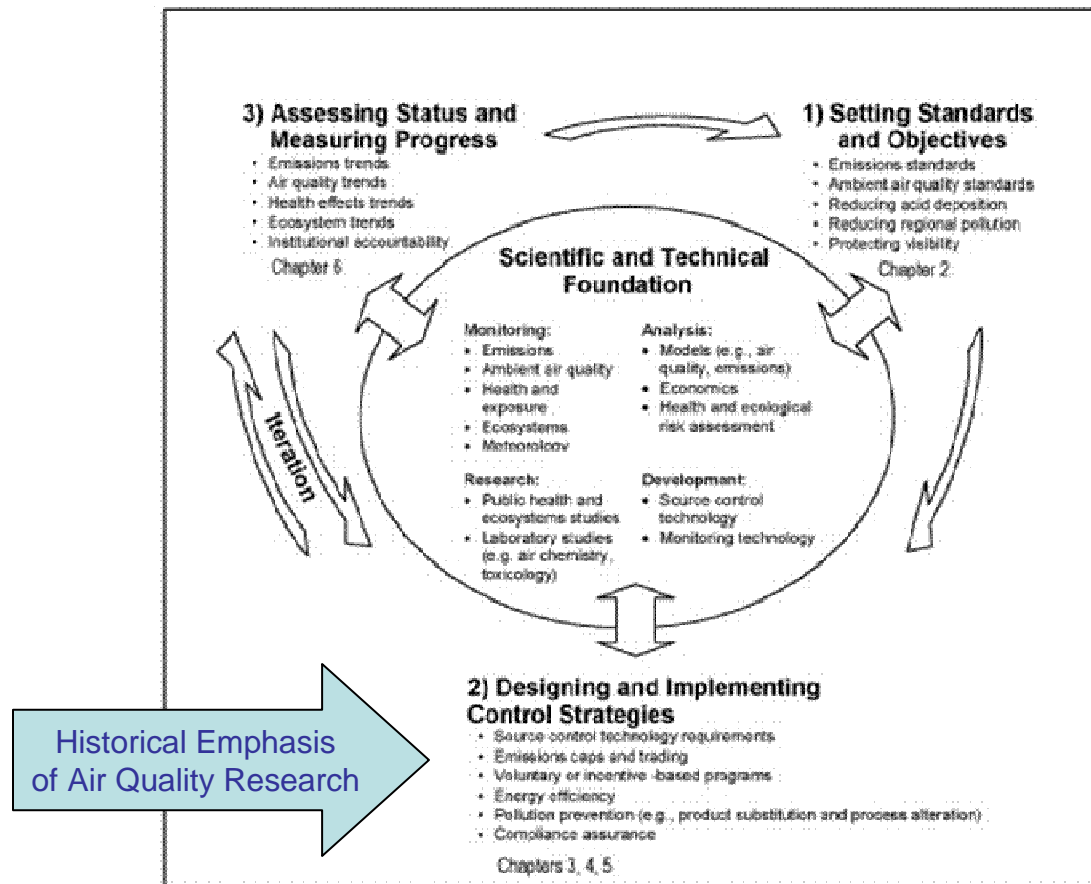The CMAS Community

Registered CMAS Users
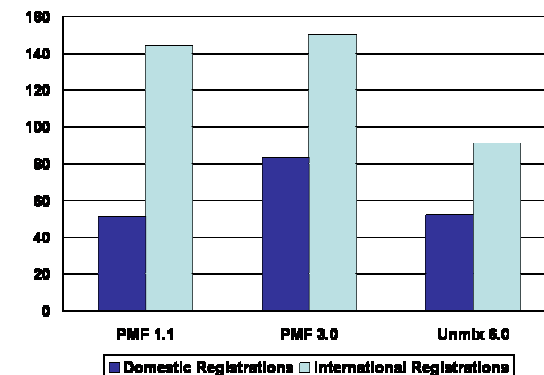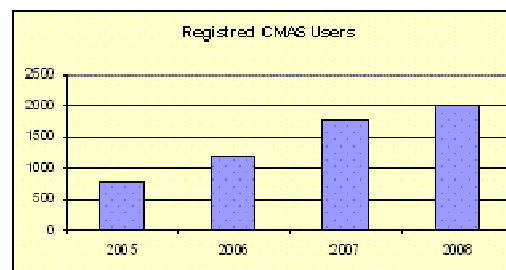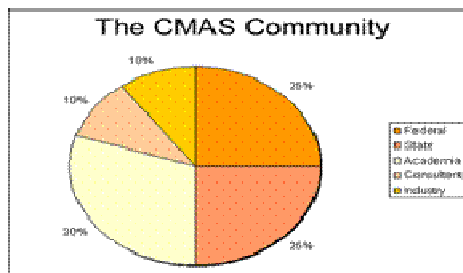
Future Directions

- Emissions
  - Enhanced source characterization
    - Aircraft, off-road vehicles, on-road vehicles with alternative fuels
    - Continued application of novel measurement methods

- Ambient Measurements
  - Near Road
  - Cleveland Multiple Air Pollutant Study (CMAPS)
  - Coarse particles
  - Methods
    - FRM/FEM requirements
    - Application and Evaluation in field work

- Models
  - 2011 CMAQ model releases
    - Enhancements for urban-scale modeling
    - Two-way interactive WRF-CMAQ meteorology/air quality model
  - Enhanced receptor-based models

- Extended applications
  - Expanded program in climate-air quality modeling and assessment
  - New ecosystem assessments (biofuels and landscape changes)
  - Multi-pollutant modeling and human exposure applications
  - Accountability – demonstrating impact of emissions, air quality changes

Future Directions:
Multi-pollutant Capabilities

December 10, 2008 — Projected NAAQS Review Schedules — 2008-2011

*Schedule may change

Today
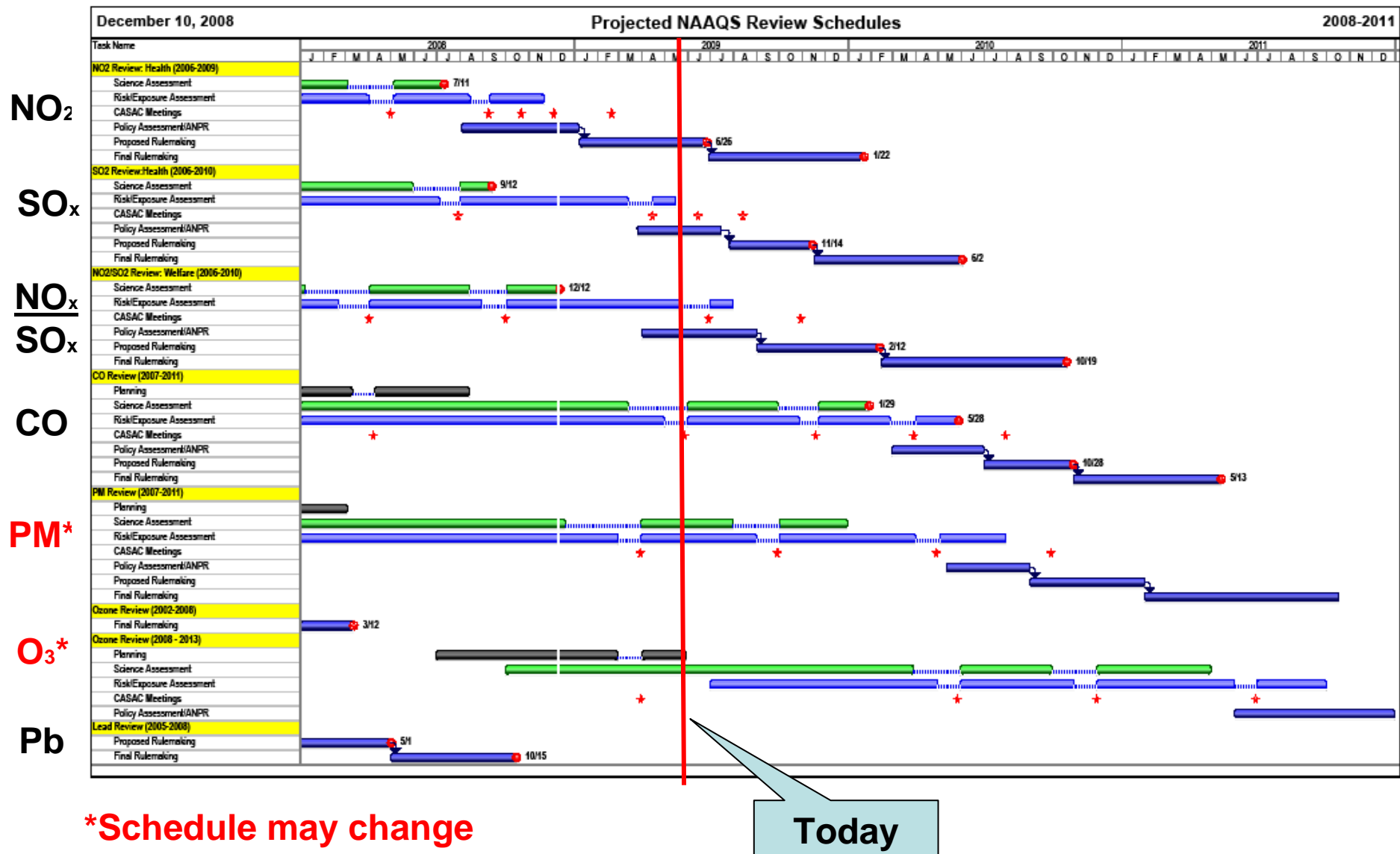
Future Directions:
Supporting All Aspects of Air Quality Management

Source: Air Quality Management in the United States (NRC 2004)